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Studies in the Sierra. No. II - Mountain Sculpture. - Origin of Yosemite Valleys.

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STUDIES IN THE SIERRA.

NO. II.—MOUNTAIN SCULPTURE.—ORIGIN OF YOSEMITE VALLEYS.

ALL the valleys and cañons of the western flank of the Sierra, between 36° and 39° north latitude, naturally classify themselves under two genera, each containing two species. One genus comprehends all the slate valleys; the other all that are built of granite. The latter is far the more important, both on account of the greater extent of its geographical range and the grandeur and simplicity of its phenomena. All the valleys of both genera are valleys of erosion. Their chief distinguishing characteristics may be seen in the following descriptions:

SLATE VALLEYS.

1. Cross-sections, V-shaped, or somewhat rounded at bottom, *walls irregular in structure*, shattered and weak in appearance, because of the development of slaty cleavage planes and joints, which also prevent the formation of plane-faced precipices. Bottom showing the naked bed-rock, or covered by rocky *débris*, and sloping in the direction of the trend. Nearly all of the foot-hill valleys belong to this species. Some of the older specimens are smoothly covered with soil, but *meadows and lakes are always wanting.*

2. More or less widened, *branching at the head.* Bottom, with meadows, or groves, or lakelets, or all together. Sections and walls about as in No. 1. Fine examples of this species occur on the head-waters of the San Joaquin.

GRANITE VALLEYS.

1. Cross-sections narrowly or widely V-shaped. Walls seldom interrupted by side-cañons, magnificently simple in structure and general surface character, and presenting plane precipices in great abundance. Bottom sloping in the direction of the trend, mostly bare, or covered with unstratified glacial and avalanche bowlders. Groves and meadows wanting.

2. *Branching at head, with beveled and heavily abraded lips at foot.* Bot-

ridges tumble pell mell
down

ridges

tom *level*, meadowed, laked, or groved. Walls usually very high, often interrupted by side-cañons. Sections as in No. 1. To this species belongs the far-famed "*Yosemite*,"* whose origin we will now discuss.

Yosemite Valley is on the main Merced, in the middle region of the range. It is about seven miles long from east to west, with an average width at bottom of a little more than half a mile, and at the top of a mile and a half. The elevation of the bottom above sea-level is about 4,000 feet. The average height of the walls is about 3,000 feet, made up of a series of sublime rock forms, varying greatly in size and structure, partially separated from one another by small side-cañons. These immense wall-rocks, ranged picturesquely together, do not stand in line. Some advance their sublime fronts far out into the open valley; others recede. A few are nearly vertical, but far the greater number are inclined at angles ranging from twenty to seventy degrees. The meadows and sandy flats outspread between, support a luxuriant growth of sedges and ferns, interrupted with thickets of azalea, willow, and brier-rose. The warmer sloping ground along the base of the walls is planted with noble pines and oaks; while countless alpine flowers fringe the deep and dark side-cañons, through which glad streams descend in falls and cascades, on their way from the high fountains to join the river. The life-giving Merced flows down the valley with a slow, stately current, curving hither and thither through garden and grove, bright and pure as the snow of its fountains. Such is Yosemite, the noblest of Sierra temples, everywhere expressing the working of Divine harmonious law, yet so little understood that it has been regarded as "an exceptional creation," or rather *exceptional destruction* accomplished by violent and mysterious forces. The argument advanced to support this view is substantially as follows: It is too wide for a water-eroded valley, too irregular for a fissure valley, and too angular and local for a primary valley originating in a fold of the mountain surface during the process of upheaval; therefore, a portion of the mountain bottom must have suddenly fallen ~~out~~, letting the superincumbent domes and ~~peaks fall rumbling~~ into the abyss, like coal into the bunker of a ship. This violent hypothesis, which furnishes a kind of Tophet for the reception of bad mountains, commends itself to the favor of many, by seeming to account for the remarkable sheerness and angularity of the walls, and by its marvelousness and obscurity, calling for no investigation, but rather discouraging it. Because we can not observe the bed-rock to ascertain whether or not it is fractured, this engulfment hypothesis seems to rest safely under cover of darkness, yet a film of lake gravel and a meadow blanket are its only concealments, and, by comparison with exposed sections in other Yosemites where the sheer walls unite with the solid, unfissured bottom, even these are in effect removed. It becomes manifest, ~~by a slight attention to~~ facts, that the hypothetical subsidence must have been limited to the valley proper, because both at the head and foot we find the solid bed-rock.

undisturbed

The breaking down of only one small portion of the mountain floor, leaving all adjacent to it undisturbed, would necessarily give rise to a ~~very~~ strongly marked line of demarcation, but no such line appears; on the contrary, the ~~un~~changed walls are continued indefinitely, both up and down the river cañon, and lose their distinguishing characteristics in a gradual manner easily accounted for by changes in the structure of the rocks and lack of concentration

sheer

* We will henceforth make use of the word Yosemite both as a specific and geographical term.

~~Now~~ According to ~~this~~ the ~~theory~~ hypothesis
now

FIG. 1.—TUOLUMNE YOSEMITE. (A A A, Glaciers.)

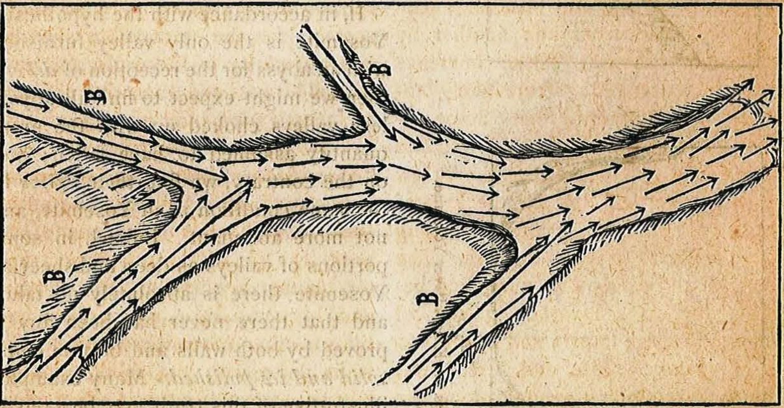

FIG. 2.—KING'S RIVER YOSEMITE. (B B B B, Glaciers.)

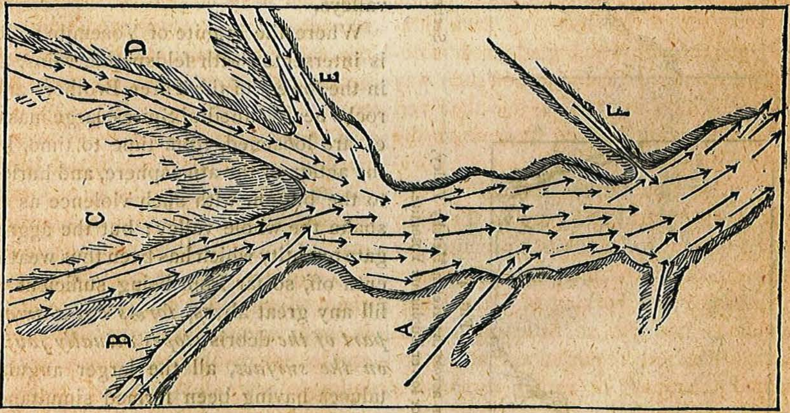

FIG. 3.—MERCED YOSEMITE. (A, Yosemite Creek Glacier; B, Hoffmann Glacier; C, Tenaya Glacier; D, South Lyell Glacier; E, Illilouette Glacier: F, Pohono Glacier.

FIG. 6. Section across the Merced Yosemite.

FIG. 5. Section across the King's River Yosemite.

FIG. 4. Section across the Hetch-Hetchy Valley, or lower Tuolumne Yosemite.

of the glacial energy expended upon them. That there is comparatively so small a quantity of *débris* at the foot of Yosemite walls is advanced as an argument in favor of subsidence, on the grounds that the valley is very old, and that a vast quantity of *débris* must, therefore, have fallen from the walls by atmospheric agencies, and that the hypothetical "abyss" was exactly required to furnish storage for it. But the Yosemite Valley is not very old. It is very young; and no vast quantity of *débris* has ever fallen from its walls. Therefore, no abyss was required for its accommodation.

If, in accordance with the hypothesis, Yosemite is the only valley furnished with an abyss for the reception of *débris*, then we might expect to find all abyssless valleys choked up with the great quantity assumed to have fallen; but, on the contrary, we find their *débris* in the same condition as in Yosemite, and not more abundant. Indeed, in some portions of valleys as deep and sheer as Yosemite there is absolutely no talus, and that there never has been any is proved by both walls and bottom being *solid and ice-polished.* Many examples illustrative of this truth may be seen in the great Tuolumne and King's River valleys.

Where the granite of Yosemite walls is intersected with feldspathic veins, as in the lowest of the Three Brothers and rocks near Cathedral Spires, large masses are loosened, from time to time, by the action of the atmosphere, and hurled to the bottom with such violence as to shake the whole valley; but the aggregate quantity which has been thus weathered off, so far from being sufficient to fill any great abyss, *forms but a small part of the* débris *slopes actually found on the surface,* all the larger angular taluses having been formed simultaneously by severe earthquake shocks that occurred three or four hundred years

Overland, June, 1874.
Studies in the Sierra, #II.
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ago, as shown by their forms and the trees growing upon them. The attentive observer will perceive that *wherever a large talus occurs, the wall immediately above it presents a scarred and shattered surface* whose area is always proportional to the size of the talus, but *where there is no talus the wall is invariably moutoneed or striated*, showing that it ~~is young and~~ hardly any has suffered little change since it came to light at the close of the glacial period. On the 23d of March, 1872, I was so fortunate as to witness the sudden formation of one of these interesting taluses by the precipitation of the Yosemite Eagle Rock by the first heavy shock of the Inyo earthquake, whereby their local character and simultaneity of formation was fully accounted for. This *new earthquake* gave rise to the formation of many *new taluses* throughout the adjacent valleys, corresponding in every particular with the older and larger ones whose history we have been considering.

X As to the important question, What part may water have played in the formation of Sierra valleys? we observe, that, as far as Yosemite is concerned, the five large streams which flow through it are universally engaged in the work of *filling it up.* The granite of the region under consideration is but slightly susceptible of water denudation. Throughout the greater portion of the main upper Merced Valley the river has not eroded its channel to a depth exceeding three feet since it first began to flow at the close of the glacial epoch, although acting under every advantage of concentration and quick descent. The highest flood-mark the young river has yet recorded upon the clean glacial tablets of its banks is only seven or eight feet above the present level, at ordinary stages. Nevertheless, the aggregate annual quantity that formerly passed down these cañon valleys was undoubtedly far greater than passes at the present time, because on the gradual recession of the glaciers at the close of the period, the supply would necessarily be

FIG. 7.

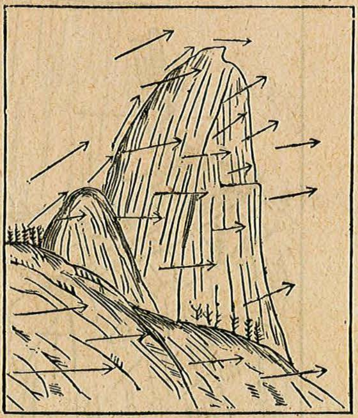

FIG. 8.

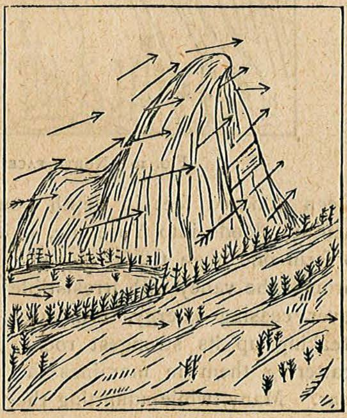

FIG. 9.

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more constant, from their melting all through the seasons. The evidence, however, is incontestable which shows that the highest floods of Sierra rivers in the upper and middle regions of the range never much exceeded those of the present time.

Five immense glaciers from five to fifteen hundred feet in depth poured their icy floods into Yosemite, uniting to form one huge trunk, moved down through the valley with irresistible and never-ceasing energy, crushing and breaking up its strongest rocks, and scattering them in moraines far and near. Many, while admitting the possibility of ice having been the great agent in the production of Yosemite valleys, conjecture that earthquake fissures, or cracks from cooling or upheaval of the earth's crust, were required to enable the glaciers to make a beginning and to guide them in the work. We have already shown ("Studies in the Sierra," in OVERLAND for May) that cleavage planes and joints exist in a latent or developed condition in all the granite of the region, and that these exert immense influence on its glacial erodibility. During five years' observation in the Sierra, I have failed to discover a single fissure of any kind, although extensive areas of clean-swept glacial pavements afford ample opportunity for their detection, did

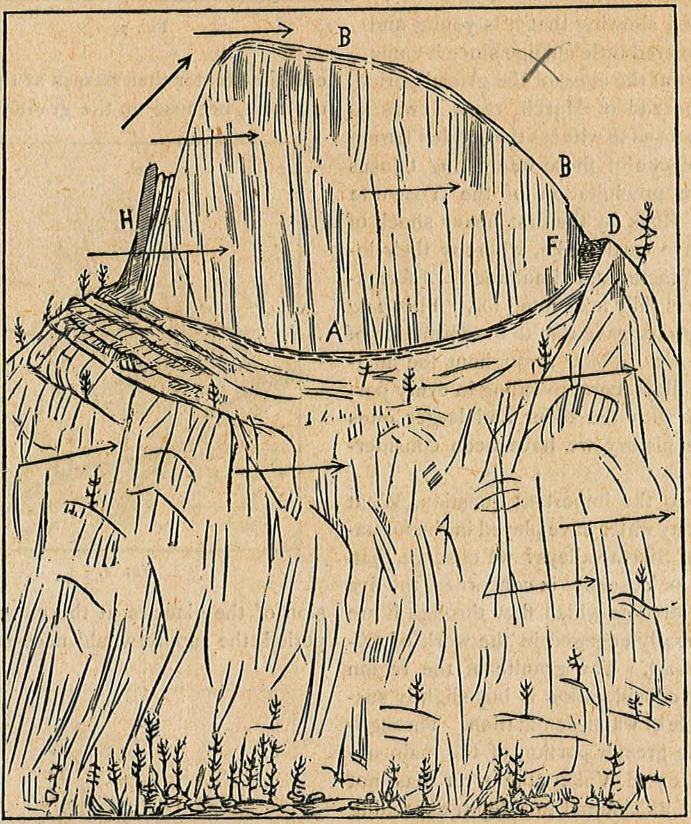

FIG. 10.—NORTH FACE OF HALF DOME, YOSEMITE VALLEY.

they exist. Deep slots, with regular walls, appearing as if sawed, or mortised, frequently occur. These are formed by the disintegration of soft seams a few inches or feet in thickness, contained between walls of stronger granite. Such is the character of the so-called fissure said to exist in a hard portion of the south wall of Yosemite, opposite the Three Brothers, so frequently quoted in speculations upon the valley's origin.

written. It would require years of enthusiastic study to master the English alphabet, if it were carved upon the flank of the Sierra in letters sixty or seventy miles long, their bases set in the foothills, their tops leaning back among the glaciers and shattered peaks of the summit, often veiled with forests and thickets, and their continuity often broken by cross-gorges and hills. So also the sculptured alphabet cañons of the Sier-

in many places

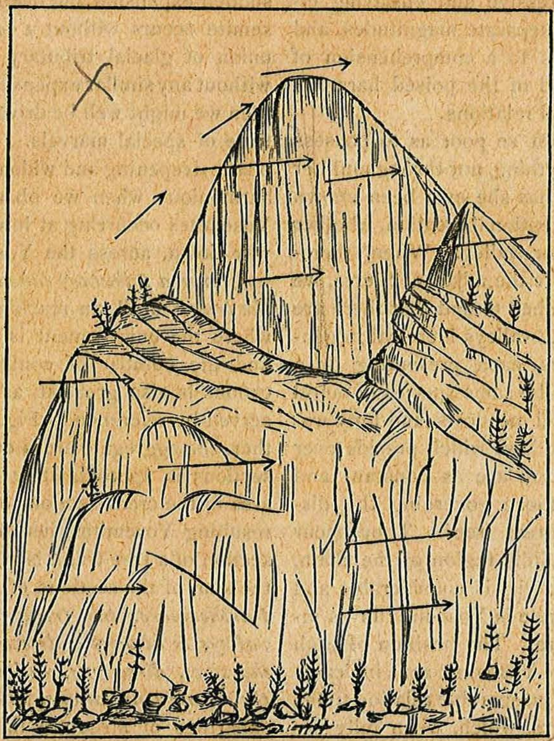

FIG. II.—NORTH FACE OF HALF DOME OF KING'S RIVER YOSEMITE VALLEY.

+ significance of their relation

The greatest effects of earthquakes on the valley, we have already noticed in avalanche taluses, which were formed by the precipitation of weak headlands, that fell like ripe fruit. The greatest obstacle in the way of reading the history of Yosemite valleys is not its complexity or obscurity, but simply the *magnitude of the characters* in which it is

throngs

ra are magnificently simple, yet demand years of laborious research for their apprehension. A thousand blurred fragments must be conned and brooded over with studious care, and kept vital and formative on the edges, ready to knit like broken living bones, while a final judgment is being bravely withheld until the entire series of phenomena has

the

be gathered into the mind with currents of thought

05914

been weighed and referred to an all-unifying, all-explaining law. To one who can leisurely contemplate Yosemite from some commanding outlook, it offers, as a whole, a far more natural combination of features than is at all apparent in partial views obtained from the bottom. Its stupendous domes and battlements blend together and manifest delicate compliance to law, for the mind is then in some measure emancipated from the repressive and enslaving effects of their separate magnitudes, and gradually rises to a comprehension of their unity and of the poised harmony of their general relations.

Nature is not so poor as to possess only one of anything, nor throughout her varied realms has she ever been known to offer an exceptional creation, whether of mountain or valley. When, therefore, we explore the adjacent Sierra, we are not astonished to find that there are many Yosemite valleys identical in general characters, each presenting on a varying scale the same species of mural precipices, level meadows, and lofty water-falls. The laws which preside over their distribution are as constant and apparent as those governing the distribution of forest trees. They occur only in the middle region of the chain, where the declivity is considerable and where the granite is Yosemitic in its internal structure. The position of each valley upon the Yosemitic zone indicates a marked and inseparable relation to the ancient glaciers, which, when fully deciphered, amounts to cause and effect. So constant and obvious is this connection between the various Yosemites and the *névé* amphitheatres which fountained the ancient ice-rivers, that an observer, experienced in these phenomena, might easily anticipate the position and size of any Yosemite by a study of the glacial fountains above it, or the position and size of the fountains by a study of their complementary Yosemite. *All Yosemites occur at the junction of two or more glacial cañons.* Thus the greater and lesser Yosemites of the Merced, Hetch-Hetchy, and those of the upper Tuolumne, those of King's River, and the San Joaquin, all occur immediately below the confluences of their ancient glaciers. If, in following down the cañon channel of the Merced Glacier, from its origin in the *névé* amphitheatres of the Lyell group, we should find that its sudden expansion and deepening at Yosemite occurs without a corresponding union of glacial tributary cañons, and without any similar expansion elsewhere, then we might well be driven to the doctrine of special marvels. But this emphatic deepening and widening becomes harmonious when we observe smaller Yosemites occurring at intervals all the way down, across the Yosemitic zone, *wherever a tributary cañon unites with the trunk*, until, on reaching Yosemite, where the enlargement is greatest, we find the number of confluent glacier-cañons is also greatest, as may be observed by reference to Fig. 1. Still further, the aggregate areas of their cross-sections is approximately equal to the area of the cross-sections of the several resulting Yosemites, just as the cross-section of a tree trunk is about equal to the sum of the sections of its branches. *Furthermore, the trend of Yosemite valleys is always a direct resultant of the sizes, directions, and declivities of their confluent cañons*, modified by peculiarities of structure in their rocks. Now, all the cañons mentioned above are the abandoned channels of glaciers; therefore, these Yosemites and their glaciers are inseparably related.* Instead of being local in character, or formed by obscure and lawless forces, *these valleys are the only great sculpture phenomena whose existence and exact positions we may confidently anticipate.*

* We shall hereafter endeavor to show how glaciers have formed their own channels.

DEPTH OF YOSEMITES.

Much stress has been laid on the mere uncompared arithmetical depth of Yosemite, but this is a character of no consequence to the consideration of its

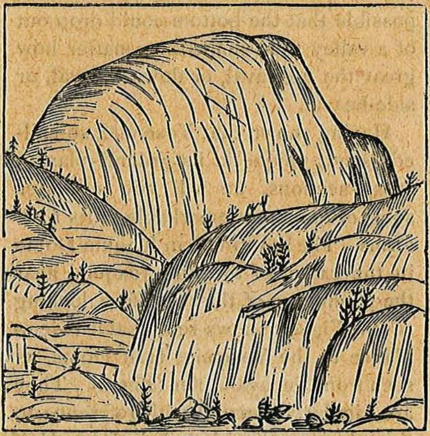

FIG. 12.

origin. The greatest Merced Yosemite is 3,000 feet deep; the Tuolumne, 2,000; another, 1,000; but what geologist would be so unphilosophical as to decide against

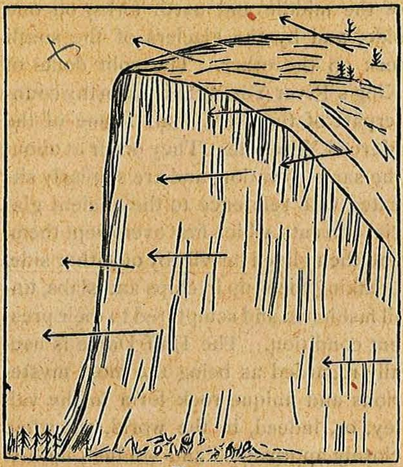

FIG. 13.

the identity of their origin from difference in depth only. One pine-tree is 100 feet high, lean and crooked, from repressing winds and the poverty of the soil which nourished it; while another, more fortunate in the conditions of its life, is 200 feet high, erect and vigorous. So, also, one Yosemite is 3,000 feet deep,

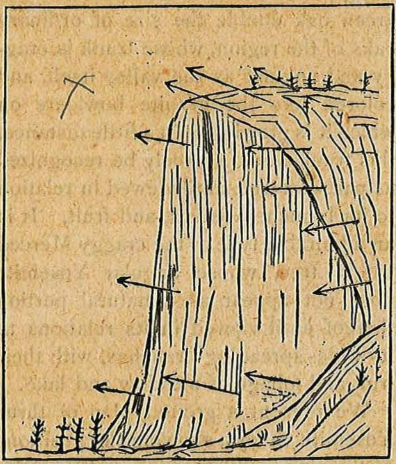

FIG. 14.

because of the favorable structure of its rocks, and the depth and number of the ice-rivers that excavated it; another is half as deep, because of the strength of

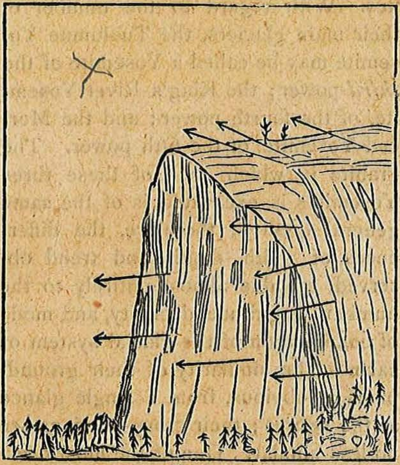

FIG. 15.

its rocks, or the scantiness of the glacial force exerted upon it. What would be thought of a botanist who should announce that our gigantic *Sequoia* was

05914

not a tree at all, offering as a reason that it was too large for a tree, and, in describing it, should confine himself to some particularly knotty portion of the trunk? In Yosemite there is an evergreen oak double the size of ordinary oaks of the region, whose trunk is craggy and angular as the valley itself, and colored like the granite bowlders on which it is growing. At a little distance, this trunk would scarcely be recognized as part of a tree, until viewed in relation to its branches, leaves, and fruit. It is an admirable type of the craggy Merced cañon-tree, whose angular Yosemite does not appear as a natural portion thereof until viewed in its relations to its wide-spreading branches, with their fruit and foliage of meadow and lake.

We present a ground-plan of three Yosemite valleys, showing the positions of their principal glaciers, and the relation of their trends and areas to them. The large arrows in Figs. 1, 2, 3, show the positions and directions of movement of the main confluent glaciers concerned in the erosion of three Yosemites. With regard to the number of their main glaciers, the Tuolumne Yosemite may be called a Yosemite of the *third* power; the King's River Yosemite, of the fourth power; and the Merced Yosemite, of the fifth power. The granite in which each of these three Yosemites is excavated is of the same general quality; therefore, the differences of width, depth, and trend observed, are due almost entirely to the number, magnitude, declivity, and mode of combination of the glacial system of each. The similarity of their ground-plans is obvious, from a single glance at the figures; their cross-sections are no less similar. One of the most characteristic from each of the valleys under consideration is shown in Figs. 4, 5, and 6, drawn on the same scale.

The perpendicularity of Yosemite walls is apt to be greatly overestimated. If the slopes of the Merced Yosemite walls were to be carefully measured with a clinometer at intervals of say 100 yards, it would be found that the average angle they make with the horizon is less than 50°, as shown in Fig. 7. It is not possible that the bottom could drop out of a valley thus shaped, no matter how great the upheaval, or down-heaval, or side-heaval.

Having shown that Yosemite, so-called, is not unique in its ground-plan or cross-sections, we will now consider some of the most remarkable of its rock forms. The beautiful San Joaquin Dome in the cañon of the San Joaquin, near the confluence of the south fork, looking south (Fig. 9), shows remarkable resemblance to the Yosemite Half Dome, as seen from Tenaya Cañon (Fig. 8). They are similarly situated with reference to the glaciers that denuded them, Half Dome having been assailed by the combined Tenaya and Hoffman glaciers, on the one side, and by the South Lyell or Merced Glacier on the other; the San Joaquin Dome, by the combined glaciers of the middle and uorth forks, on one side, and by the glaciers of the south fork on the other. The split dome of King's River Yosemite is a worthy counterpart of the great Half Dome of the Merced Yosemite. They occur at about the same elevation, and are similarly situated with reference to the ancient glacial currents, which first overswept them, and then glided heavily by on either side, breaking them up in chips and slabs, until fashioned and sculptured to their present condition. The Half Dome is usually regarded as being the most mysterious and unique rock form in the valley, or, indeed, in the world, yet when closely approached and studied, its history becomes plain.

From A to B, Fig. 10, the height is about 1,800 feet; from A to the base, 3,000. The upper portion is almost absolutely plain and vertical, the lower is inclined at an angle with the horizon of about 37°. The observer may ascend from the south side to the shoulder of the dome at D, and descend along the face toward A H. In the notch at F a section of the dome may be seen, showing that it is there made up of immense slabs set on edge. These evidently have been produced by the development of cleavage planes, which, cutting the dome perpendicularly, have determined the plane of its face, which is the most striking characteristic of the rock. Along the front toward A H may be seen the stumps of slabs which have been successively split off the face. At H may be seen the edges of residual fragments of the same slabs. At the summit, we perceive the cut edges of the concentric layers which have given the curved dome outline, B B. At D, a small gable appears, which has been produced by the development of diagonal cleavage planes, which have been cut in front by vertical planes. After the passage of the main Tenaya Glacier in the direction of the arrows, small glacierets seem to have flowed down in front, eroding shallow groove channels in the direction of greatest declivity; and even before the total recession of the main glacier a wing-shaped ice-slope probably leaned back in the shadow, and with slow action eroded the upper portion of the dome. All the rocks forming the south walls of deep Yosemitic cañons exhibit more or less of this light after-sculpture, effected in the shade after the north sun-beaten rocks were finished.

The south side of the dome has been heavily moutoneed by the Lyell Glacier, but is, nevertheless, nearly as vertical as the north split side. The main body of the rock corresponds in form and attitude with every other rock similarly situated with reference to ice-rivers, and to elevation above sea-level; the special split dome-top being, as we have seen, a result of special structure in

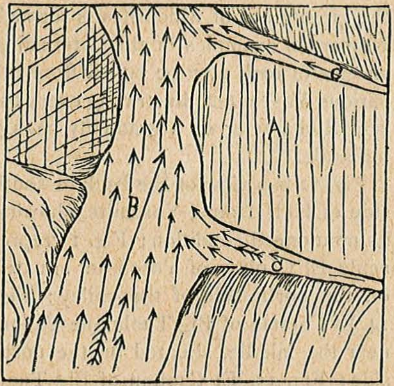

FIG. 16.

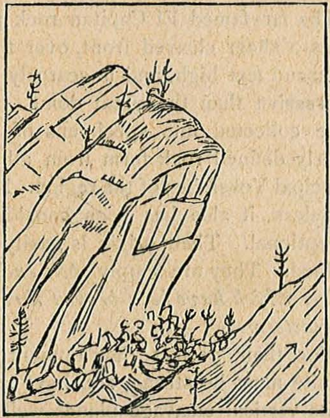

FIG. 17.

FIG. 18.

the granite out of which it was formed. Numerous examples of this interesting species of rock may be culled from the various Yosemites, illustrating every essential character on a gradually changing scale.

Fig. 12 is a view of the back or south side of Half Dome, Yosemite, showing its moutoneed condition; Fig. 13 represents El Capitan of Yosemite, situated on the north side of the valley; Fig. 14, El Capitan of Big Tuolumne Cañon, near the middle, situated on the north side; Fig. 15, El Capitan of Big Tuolumne Cañon, near the head, situated on the north side.

The far-famed El Capitan rock presents a sheer cleaved front, over three thousand feet high, and is scarcely less impressive than the great dome. We have collected fine specimens of this clearly defined rock form from all the principal Yosemites of the region. Nevertheless, it also has been considered exceptional. Their origin is easily explained. They are simply *split ends of ridges which have been broken through by glaciers.*

For their perfect development the granite must be strong, and have some of its vertical cleavage planes well developed, nearly to the exclusion of all the others, especially of those belonging to the diagonal and horizontal series. A powerful trunk glacier must sweep past in front nearly in the direction of its cutting planes, with small glaciers, tributary to the first, one on each side of the ridge out of which the Capitan is to be made. This arrangement is illustrated in Fig. 16, where A represents a horizontal section of a Capitan rock, exposing the edges of the cleavage planes which determined the characters of its face; B, the main glacier sweeping down the valley in front; and C C, the tributaries isolating it from the adjacent softer granite. The three Capitans figured stand thus related to the glaciers of the region where they are found. I have met with many others, all of which are thus situated, though in some instances one or both of the side glaciers had been wanting, leaving the resulting Capitan less perfect, considering the bold advancing Yosemite Capitan as a typical form.

When the principal surface features of the Sierra were being blocked out, the main ice-sheet was continuous and moved in a southerly direction, therefore the most perfect Capitans are invariably found on the north sides of valleys trending east and west. The reason will be readily perceived by referring to Fig. 8 of "Mountain Sculpture," No. 1, in OVERLAND for May.

To illustrate still further how fully the split fronts of rocks facing deep cañons have the angles at which they stand measured by their cleavage planes, we give two examples (Figs. 17 and 18) of leaning fronts from the cañon of the north fork of the San Joaquin River. Sentinel and Cathedral rocks also are found in other glacial cañons, and in every instance their forms, magnitudes, and positions are obviously the necessary results of the internal structure and general mechanical characters of the rocks out of which they were made, and of the glacial energy that has been brought to bear on them. The abundance, therefore, of lofty angular rocks, instead of rendering Yosemite unique, is the characteristic which unites it most intimately with all the other similarly situated valleys in the range.